SCIENCE FOR GLASS PRODUCTION

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TESTING LAMINATED GLASS FOR IMPACT RESISTANCE

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Comparative testing of laminated glass made up by different combinations for impact resistance has been performed. The testing corroborates the possibility of using glass subjected to special thermal treatment (STT) in the production of impact-resistant laminated glass. Glasses based on STT glass satisfy the impact resistance requirements of GOST R 51136–98, and their thickness and weight are a factor of 1.5 less .

Contemporary trends in the world glass industry are generally directed toward producing glass with additional properties. Such are protective laminated glasses intended for vehicles and administrative, public, and residential buildings, where there is need to protect human life and material assets.

According to GOST R 51136–98, protective laminated glass is made of various combinations of glass plates, such as silicate glass, silicate glass with organic glass, polycarbonate, or strengthening film bonded by polymer materials and represents a multilayer block possessing protective properties. Such products traditionally use annealed glass and polyvinylbutyral film (PVB film).

The laminated glass that is the most available and commonly used in construction is impact-resistant glass withstanding multiple impacts of a freely falling body with rated parameters. The impact in testing is performed by a hardened steel ball weighing 4.11 kg of diameter 100 mm, while the glass is fixed in a special frame. Depending on the protection class (A1, A2, and A3), the height of dropping the ball is 3.5, 6.5, and 9.5 m, respectively.

It should be noted that laminated glass is traditionally made of low-strength annealed glass; consequently, such products are very bulky (from 6 to 30 mm thick) and heavy, and therefore fortified frames are required for glazing. The effect of a "thin" impact-resistant glass (less than 9 mm) was achieved by depositing numerous protection film layers on both sides of an annealed glass sheet, and to improve the service properties, expensive scratch-resistant coating had to be applied on top of the surface layers.

A previously developed variant permitting a significant decrease in the thickness of impact-resistant laminated glass uses PVB film together with glass subjected to special thermal treatment (STT glass) [1].

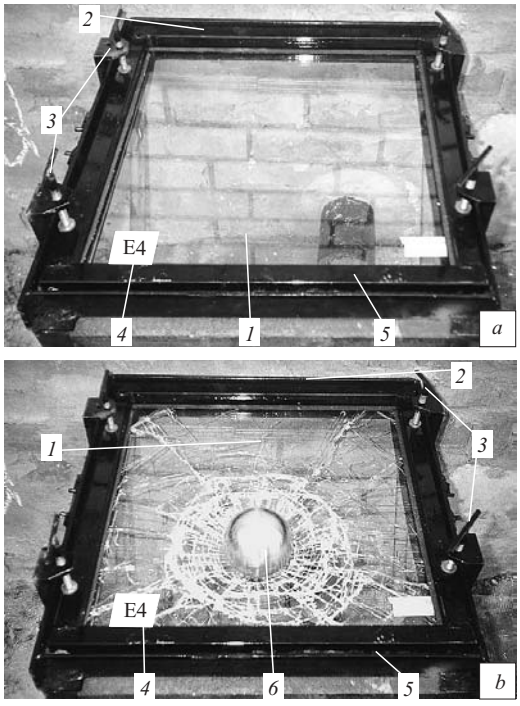

Fig. 1. The frame for test product fixation after the product is fixed and marking applied (*a*) and after the ball is dropped (*b*): *1*) glass sample; *2*) frame; *3*) cramps; *4*) marking of the product; *5*) hold-down frame; *6*) steel ball.

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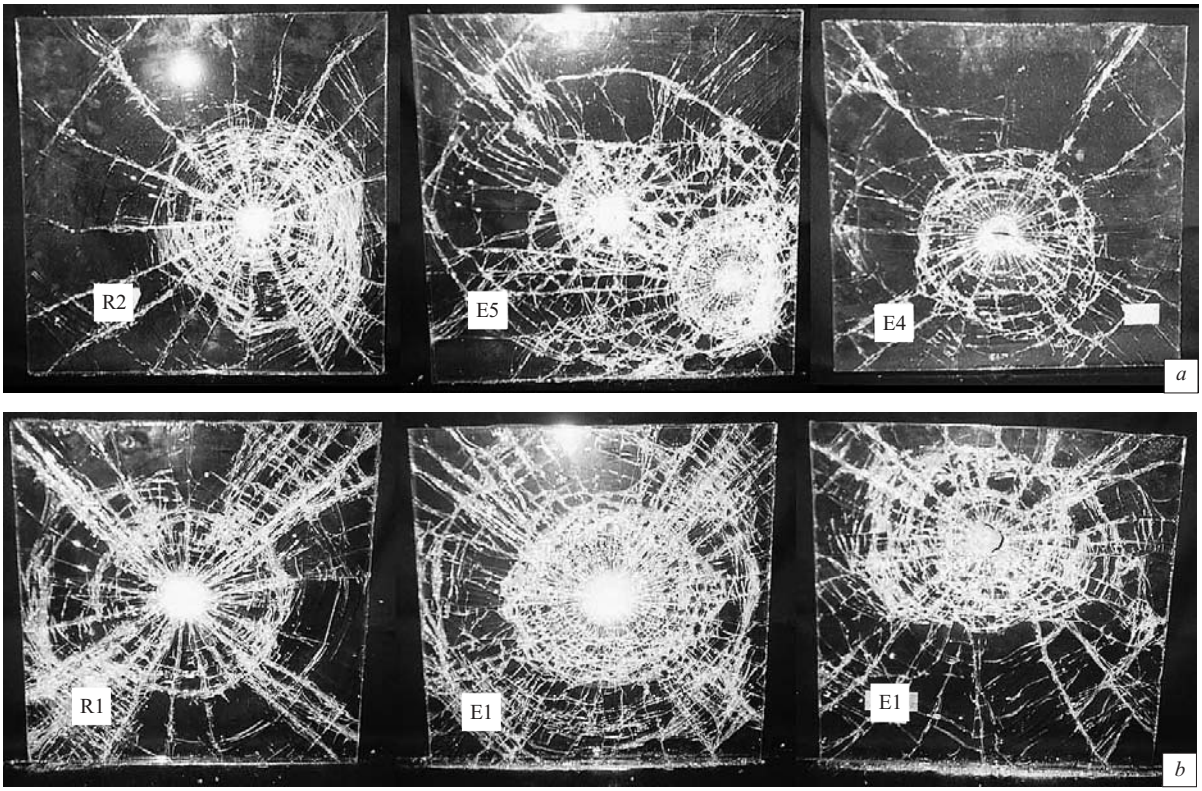

Fig. 2. Glass samples of protection classes A1 (*a*) and A2 (*b*) after testing.

The purpose of the experiment was to verify the reliability of this assumption. Comparative testing of impact-resistant glasses of different classes of protection was carried out, both of traditional laminated glasses (reference samples R) and experimental combinations (samples E). The finished products in both variants were to have similar strength, but it was planned to decrease the total number of layers and the total thickness in experimental samples by a factor of 1.5 compared to the reference samples, due to using STT glass. The experimental set of STT glass sheets was produced on the vertical glass-hardening line of an original design at the Ural Glass Company according to the known hardening regimes [2, 3] taking into account the required strength [4].

The products R and E were simultaneously prepared at the Ural Glass Company using the following scheme: preparation of glass and film, stacking, rolling, autoclave treatment, and control of finished products. Comparative tests performed under conditions maximally close to the requirements of GOST R 51136–98 were accompanied by photography and videotaping.

To conduct comparative strength tests, a special frame was constructed providing rigid fixation of laminated products with a surface area of 500 × 500 mm, and an impact sphere was produced complying with the standard requirements (Fig. 1).

The formulas of finished articles are listed in Table 1. According to the standard, the digits without brackets indicate the thickness of the glass layer in millimeters, the digits in rounds brackets indicate the initial thickness of the intermediate layer, i.e., PVB film in millimeters, and the digit in square brackets indicates the thickness of the outer protective film layer (if such film is absent, no digit is given).

The testing method includes the following stages:

– the product tested was rigidly fixed in the frame with rubber lining, and the glass surfaces were washed and marking applied indicating the sample name and the product formula;

– the sphere was fixed above the product center at a height of 3.5 or 6.5 m (depending on the protection class);

– the ball was dropped on the glass;

– the nature of the destruction was registered;

TABLE 1

Sample	Product formula	Protection class	Product thickness, mm	Product weight, kg
R2	3(0.76)3(0.38)3	A1	10.1	6.90
E4	3(0.38)3[0.28]	A1	6.7	4.60
E5	3(0.76)3	A1	6.7	4.60
R1	5(0.76)5(0.76)5	A2	16.5	9.79
E1	5(0.76)5	A2	10.7	6.50
E1′	5(0.76)5[0.28]	A2	11.0	6.70

TABLE 2

Sample	Breakthrough	Through opening	Opening shape	Opening size, mm	Crater depth, cm	Crumbling of fragments	Height of rebound of the ball, cm
R2	No	No	–	–	3.5	Yes	5
E5 (first drop)*	No	Yes	Linear	50 × 1	4.5	Yes	15
E5 (second drop)	No	No	–	–	3.0	No	25
E4	No	Yes	Rectangular	35 × 5	5.0	Yes	1
R1	No	Yes	Linear	25	1.5	Yes	40
E1	Yes	Yes	Round	100	4.5	Yes	–
E1′	No	Yes	Linear	35	1.5	Yes	70

* As a consequence of unfortunate settling of the ball, it fell near the frame.

– the product was removed from the frame, the glass fragments were cleared away, and the frame was prepared for the next sample.

It is established that all products except for sample E1 have successfully passed the testing (Fig. 2 and Table 2).

The successful testing of the experimental samples corroborates the appropriateness of using strengthened glass in producing impact-resistant laminated glass. The conversion from annealed glass to STT glass significantly reduces the amount of electricity needed for rolling and autoclave treatment and significantly reduces the labor consumption in the process by reducing the total number of layers in the product. A decrease in the thickness and weight of the product and its improved light transmission will make this type of product more attractive for customers.

REFERENCES

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